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EFFECTS OF PLASTIC DEFORMATION ON TENSILE TEST SPECIMENS BY VARIATIONS IN THE STRAINING RATE

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EFFECTS OF PLASTIC DEFORMATION ON TENSILE TEST SPECIMENS BY VARIATIONS IN THE STRAINING RATE

SUBMITTED UNDER

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The tests described in this report were conducted between October and December 1957.

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EFFECTS OF PLASTIC DEFORMATION ON TENSILE TEST SPECIMENS BY VARIATIONS IN THE STRAINING RATE

PURPOSE:

The purpose of this investigation was to establish a maximum strain rate for performing tensile tests on metallic materials in the plastic range.

SUMMARY:

The effect of strain rate in the plastic range on the percent elongation, percent reduction of area, and the rise in specimen temperature due to straining 5052-0 aluminum alloy, AZ80A magnesium alloy and annealed SAE 4130 steel was determined.

Eleven specimens of SAE 4130 steel which were heat treated to approximately 200,000 psi were also tensile tested at various strain rates to determine how the rise in temperature due to straining compared with the annealed SAE 4130 steel specimens.

It was found that strain rate in the plastic range had no significant effect on the percent elongation or percent reduction of area properties of the materials tested. The increase in temperature due to increased strain rates was greater for the SAE 4130 steel heat treated to 200,000 psi than for the annealed 4130 steel, but in neither case did it significantly affect the percent elongation or percent reduction of area properties.

EFFECTS OF PLASTIC DEFORMATION ON TENSILE TEST SPECIMENS BY VARIATIONS IN THE STRAINING RATE

OBJECT:

The object of this test was to determine the effect of strain rate in a standard tension test on specimen temperature and the elongation and reduction of area properties of 5052-0 aluminum alloy, AZ80A magnesium alloy and SAE 4130 steel in the annealed and heat treated conditions.

PROCEDURE:

Standard 0.505 in. diameter tensile specimens*were fabricated from 5052-0 aluminum alloy, AZ80A magnesium alloy and anealed SAE 4130 steel. Additional specimens were also prepared using SAE 4130 steel heat treated to approximately 200,000 psi. All specimens were marked to retain their identity as follows:

MATERIAL	SPECIMEN NUMBERS
5052-0	A-1 thru A-15
SAE 4130, annealed	B-1 thru B-20
AZ80A	C-1 thru C-18
SAE 4130, heat treated	D-1 thru D-11

Tension tests were performed on a 120,000 lb. Baldwin universal testing machine which was equipped with an MA-1 microformer recorder and a Peter's strain pacer. All specimens were tensile tested using a strain rate of .005 in/in per minute for the elastic range. After the yield point at .2% offset was reached the strain rate was increased to a predetermined value until failure occurred. Various strain rates were used in the plastic range to determine their effect on the ductility of each of the materials tested.

The increase in specimen temperature due to straining was measured with a thermocouple which was manually held in contact with the necked down portion of each specimen.

Since the Peter's strain pacer was used on each specimen until failure occurred, it was necessary to use an extensometer with a range of at least one inch. A Baldwin model KSM extensometer was used for strain rates from 0.0125 in/in per minute up to and including 0.25 in/in per minute, and a model PS8M was used for all other strain rates.

* Specimen Type R1, Method 211, Federal Test Method Std. No. 151

The amount of time required for failure to occur after 0.2% offset yield was obtained was from 3 to 8 seconds for the fastest strain rates used for the different materials, and from 8 to 23 minutes for the slowest rates used.

RESULTS:

Results are shown in Tables I, II, III and IV, and graphically in Figures 1, 2, 3 and 4. Photographs of two of the failed specimens of 4130 steel which were heat treated to approximately 200,000 psi are shown in Figure 5.

DISCUSSION:

Ultimate strength, yield strength, percent elongation, percent reduction of area and the rise in specimen temperature due to straining are shown for various strain rates in Tables I, II, III and IV.

The effect of strain rate on percent elongation, percent reduction of area, and the rise in specimen temperature due to straining for each material are shown in Figures 1, 2, 3 and 4.

The 4130 steel which was heat treated to approximately 200,000 psi exhibited two different types of fractures; one a rosette type fracture at slow strain rates of 0.25 in/in per minute and slower, and the other a cup and cone type fracture at faster rates. A photograph of these two type failures is shown in Figure 5.

CONCLUSIONS:

The rate of straining has no significant effect on the percent elongation or percent reduction of area properties of 5052-O aluminum alloy, annealed SAE 4130 steel or AZ80A magnesium alloy when these materials are tensile tested using standard procedures.

The increase in temperature due to straining was higher for SAE 4130 steel heat treated to approximately 200,000 psi than for annealed 4130 steel, but in neither case did it significantly affect the percent elongation or the percent reduction of area properties.

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TABULATION SHEET

TABLE I

MAT'L - ALUMINUM ALLOY 5052-O

SPEC. NO.	DIAM. (IN.)	AREA (IN^2)	YIELD (LBS)	STR. (PSI)	ULT. (LBS)	T. S. (PSI)	ELONG. IN 2 IN. (%)	R.A.(1) (%)	STRAIN RATE (IN./IN./MIN)	RISE IN TEMP. (°F)
A-3	.5050	.2003	3000	14,950	5525	27,580	27	63.8	.0125	NONE
A-7	.5060	.2009	3025	15,060	5585	27,800	31	64.4	.0125	NONE
AVERAGE							29	64.1		
A-9	.5055	.2005	2900	14,450	5400	26,970	30	64.2	.125	NONE
A-14	.5062	.2011	2800	13,900	5400	26,850	30	67.2	.125	8°
AVERAGE							30	65.7		4°
A-4	.5059	.2010	2750	13,680	5350	26,620	31	68.1	.25	13°
A-12	.5055	.2005	2790	13,900	5335	26,600	31	67.3	.25	9°
A-15	.4715	.1745	2490	14,250	4675	26,750	30	64.8	.25	10°
AVERAGE							30.7	66.7		11.3°
A-1	.5064	.2011	2705	13,500	5290	26,300	30	67.6	1.0	13°
A-2	.5055	.2005	2755	13,740	5325	26,560	30	67.1	1.0	14°
AVERAGE							30	67.3		13.5°
A-5	.5035	.1990	2745	13,790	5175	26,010	27	68.6	2.0	14°
A-6	.5030	.1987	2650	13,340	5290	26,620	30	67.4	2.0	14°
A-11	.5060	.2009	2800	13,940	5185	25,810	29	66.0	2.0	8°
AVERAGE							28.7	67.3		12°
A-8	.5050	.2002	2800	13,950	5205	26,000	28	64.2	2.5	13°
A-10	.5055	.2005	2750	13,720	5155	25,750	30	65.6	2.5	13°
A-13	.5055	.2005	3000	14,930	5250	26,170	32	67.3	2.5	13°
							30	65.7		13°

(1) R.A. - - REDUCTION OF AREA

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TABULATION SHEET

TABLE II — MAT'L - SAE 4130 (ANNEALED)

SPEC. NO.	DIAM. (IN)	AREA (IN^2)	YIELD STR. (LBS)	YIELD STR. (PSI)	ULT. (LBS)	T. S. (PSI)	ELONG. IN 2 IN. (%)	R.A.[1] (%)	STRAIN RATE (IN/IN/MIN)	RISE IN TEMP. (°F)
B-1	.5040	.1995	11,600	58,145	17,800	89,300	28.0	55.8	.0125	4°
B-2	.5040	.1995	11,580	58,045	17,800	89,300	32.0	56.9	.0125	6°
AVERAGE							30.0	56.3		5°
B-6	.5040	.1995	11,700	58,645	17,820	89,320	28.5	55.8	.125	56°
B-7	.5015	.1975	11,600	58,735	17,680	89,520	28.0	55.7	.125	64°
AVERAGE							28.3	55.7		60°
B-3	.5020	.1979	11,680	59,020	17,840	90,150	28.0	55.7	.25	—
B-4	.5020	.1979	11,600	58,615	17,920	90,550	26.5	55.2	.25	—
B-5	.5040	.1995	11,400	57,140	17,980	90,130	26.5	55.3	.25	—
B-10	.5055	.2007	12,000	59,790	18,240	90,880	25.5	55.6	.25	92°
AVERAGE							26.5	55.5		92°
B-8	.5045	.1999	11,400	57,030	18,260	91,350	26.5	54.6	1.0	—
B-9	.5060	.2011	11,800	58,680	18,360	91,300	24.5	54.1	1.0	106°
B-11	.5020	.1979	—	—	18,240	92,170	26.0	54.1	1.0	128°
AVERAGE							25.7	54.3		117°
B-12	.5050	.2003	12,000	59,910	18,460	92,160	26.0	54.4	1.5	146°
B-13	.5055	.2007	11,550	57,550	18,530	92,330	26.0	53.7	1.5	—
B-14	.5045	.1999	11,770	58,880	18,340	91,750	26.0	54.3	1.5	140°
AVERAGE							26.0	54.1		143°
B-15	.5045	.1999	11,660	58,330	18,240	91,250	26.5	55.1	2.0	—
B-16	.5025	.1983	11,400	57,490	18,080	91,170	26.5	54.8	2.0	—
B-17	.5030	.1987	11,300	56,870	18,150	91,340	26.0	52.9	2.0	—
AVERAGE							26.3	54.3		
B-18	.5045	.1999	11,150	55,780	18,240	91,250	28.0	54.8	2.5	—
B-19	.5025	.1983	11,960	60,310	18,240	91,980	25.5	54.2	2.5	—
B-20	.5040	.1995	11,500	57,645	18,340	91,930	26.5	53.1	2.5	—
AVERAGE							26.7	54.0		

(1) R. A. - REDUCTION OF AREA

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TABULATION SHEET

TABLE III   MAT'L - MAGNESIUM ALLOY AZ80-A

SPEC. NO.	DIAM. (in)	AREA (in²)	YIELD (LBS)	STR. (PSI)	ULT. (LBS)	T. S. (PSI)	ELONG. IN 2 IN. (%)	R.A.(2) (%)	STRAIN RATE (in/in/min)	RISE IN TEMP. (°F)	
C-3	.5055	.2007	7,200	35875	10,040	50,025	—	—	.0125	—	(1)
C-10	.4905	.1890	6,820	36,085	9,770	51,695	16	23.5	.0125	NONE	
C-2	.5054	.2006	7,150	35,640	9,800	48,850	—	—	.05	—	(1)
C-4	.5052	.2003	7,150	35,695	10,080	50,325	—	—	.05	—	(1)
C-5	.5035	.1991	7,200	36,160	10,080	50,630	—	—	.05	—	(1)
C-6	.4906	.1890	6,720	35,555	9,400	49,735	—	—	.05	—	(1)
C-7	.4895	.1882	6,730	35,760	9,560	50,800	15	20.7	.05	24°	
C-11	.4895	.1882	6,800	36,130	9,500	50,480	15	22.8	.05	10°	
AVERAGE							15	21.7		17°	
C-8	.4895	.1882	6,880	36,555	9,500	50,480	14	18.1	.075	16°	
C-9	.4895	.1882	6,790	36,080	9,490	50,425	14	21.8	.075	14°	
AVERAGE							14	20.0		15°	
C-1	.5060	.2011	7,130	35,450	9,500	47,240	—	—	.125	—	(1)
C-19	.4853	.1850	6,690	36,160	9,280	50,160	15	21.9	.125	20°	
C-12	.4890	.1878	6,800	36,210	9,360	49,840	14	20.5	.25	26°	
C-13	.4895	.1882	6,760	35,920	9,440	50,160	14	17.7	.25	20°	
AVERAGE							14	19.1		23°	
C-14	.4900	.1886	6,680	35,420	9,350	49,575	13	18.3	.5	31°	
C-15	.4890	.1878	6,710	35,730	9,290	49,470	13	20.1	.5	24°	
AVERAGE							13	19.2		27.5°	
C-16	.4720	.1750	6,300	36,000	8,720	49,830	14	18.6	.75	25°	
C-17	.4895	.1882	6,620	35,175	9,320	49,520	15	21.4	.75	27°	
AVERAGE							14.5	20.0		26°	
C-18	.4895	.1882	6,670	35440	9,240	49,100	14	21.0	1.00	30°	

(1)-FAILURE OCCURRED OUT OF GAGE LENGTH

(2) - R.A. - REDUCTION OF AREA

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TABULATION SHEET

TABLE IV

MAT'L - SAE 4130 (HT. TREATED)

SPEC. NO.	DIAM. (IN.)	AREA (IN^2)	YIELD (LBS)	STR. (PSI)	ULT. (LBS)	T. S. (PSI)	ELONG. IN 2 IN. (%)	R.A.(1) (%)	STRAIN RATE (IN/IN/MIN)	RISE IN TEMP. (°F)
D-7	.5056	.2008	39,900	198,700	41,700	207,670	12	49.6	.0125	10°
D-6	.5038	.1993	39,750	199,450	41,750	209,480	12	50.3	.125	—
D-9	.5045	.1999	39,500	197,600	41,600	208,100	12	49.1	.125	76°
D-10	.5047	.2001	39,550	197,650	41,800	208,900	11	48.6	.125	72°
AVERAGE							11.7	49.3		74°
D-5	.5039	.1994	39,550	198,350	41,850	209,880	12	50.3	.25	87°
D-8	.5019	.1978	38,700	195,650	41,200	208,290	12	49.9	.25	100°
AVERAGE							12	50.1		93.5
D-3	.5026	.1984	39,400	198,590	41,550	209,430	12	47.6	1.0	136°
D-4	.5035	.1991	39,300	197,390	41,550	208,690	11	47.2	1.0	200°
D-11	.4990	.1956	39,600	202,450	41,000	209,610	10	46.2	1.0	138°
AVERAGE							11	47.0		158°
D-1	.5020	.1979	39,500	199,600	41,400	209,200	12	48.3	1.5	—
D-2	.5036	.1992	39,300	197,290	41,600	208,840	12	48.6	1.5	—
AVERAGE							12	48.4		

(1) R.A. - REDUCTION OF AREA

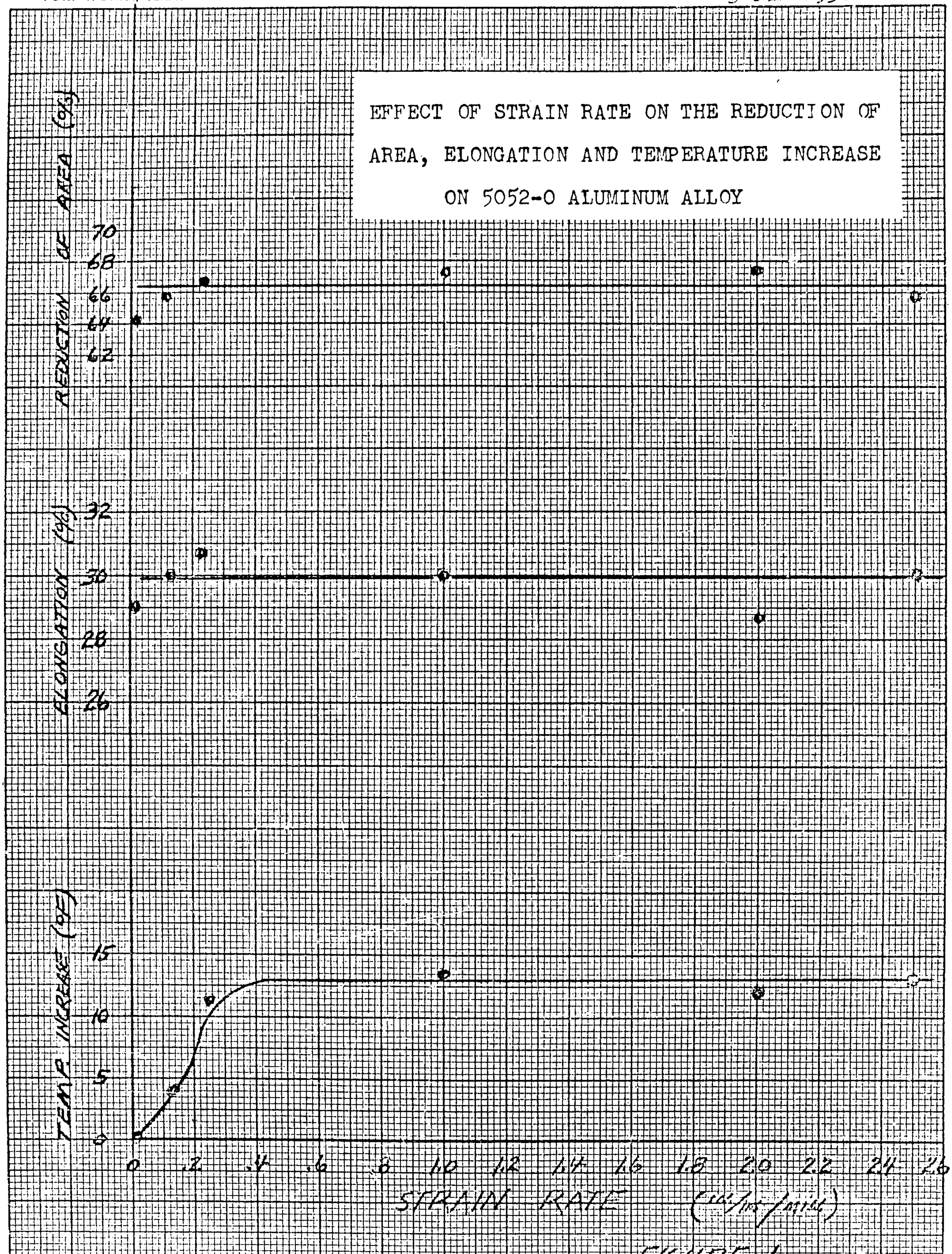

EFFECT OF STRAIN RATE ON THE REDUCTION OF AREA, ELONGATION AND TEMPERATURE INCREASE ON 5052-O ALUMINUM ALLOY
REDUCTION OF AREA (%)
70
68
66
64
62
ELONGATION (%)
32
30
28
26
TEMP INCREASE (°F)
15
10
5
0
0 .2 .4 .6 .8 1.0 1.2 1.4 1.6 1.8 2.0 2.2 2.4 2.6
STRAIN RATE (in/in/min)

FIGURE 1

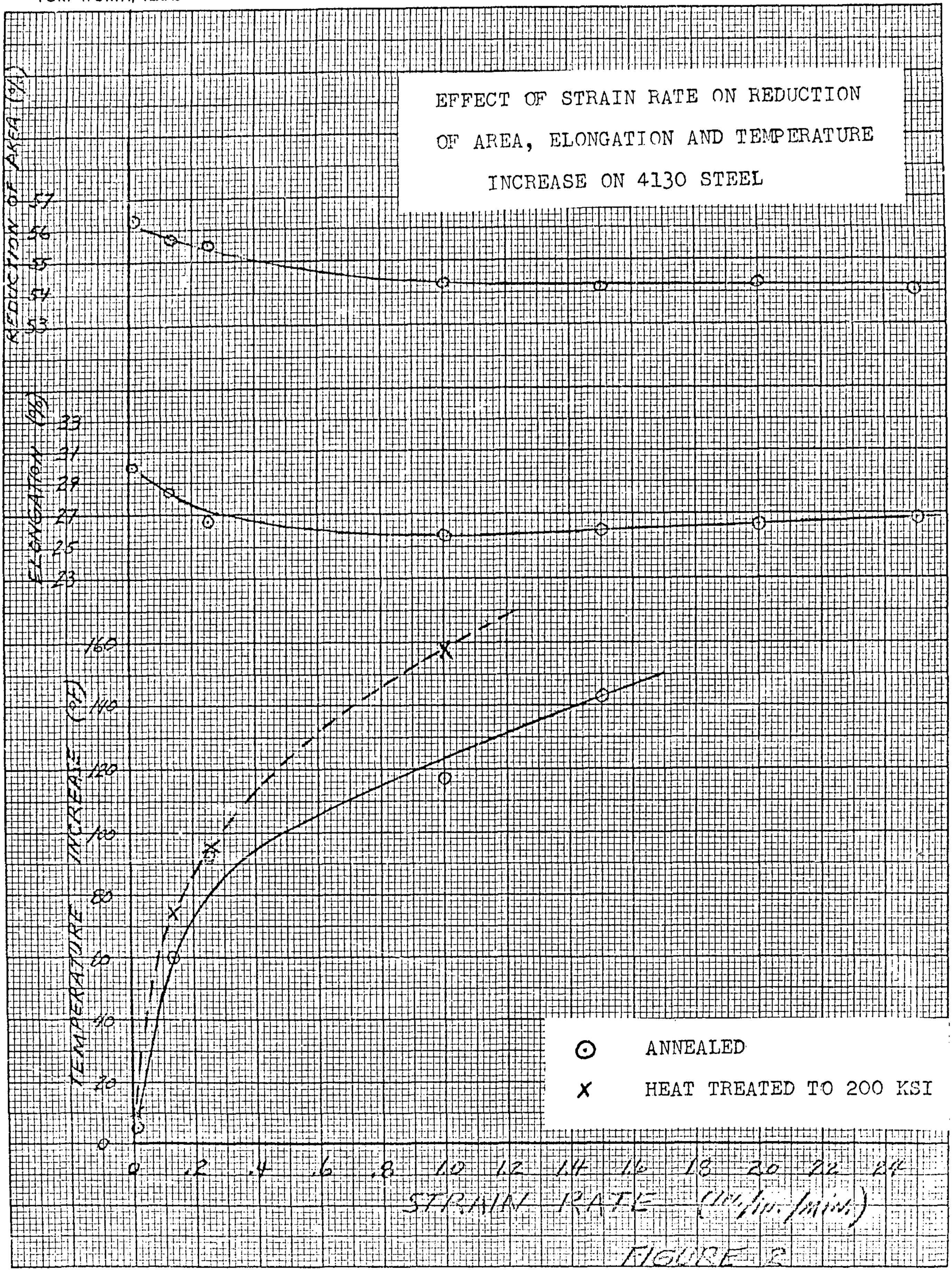
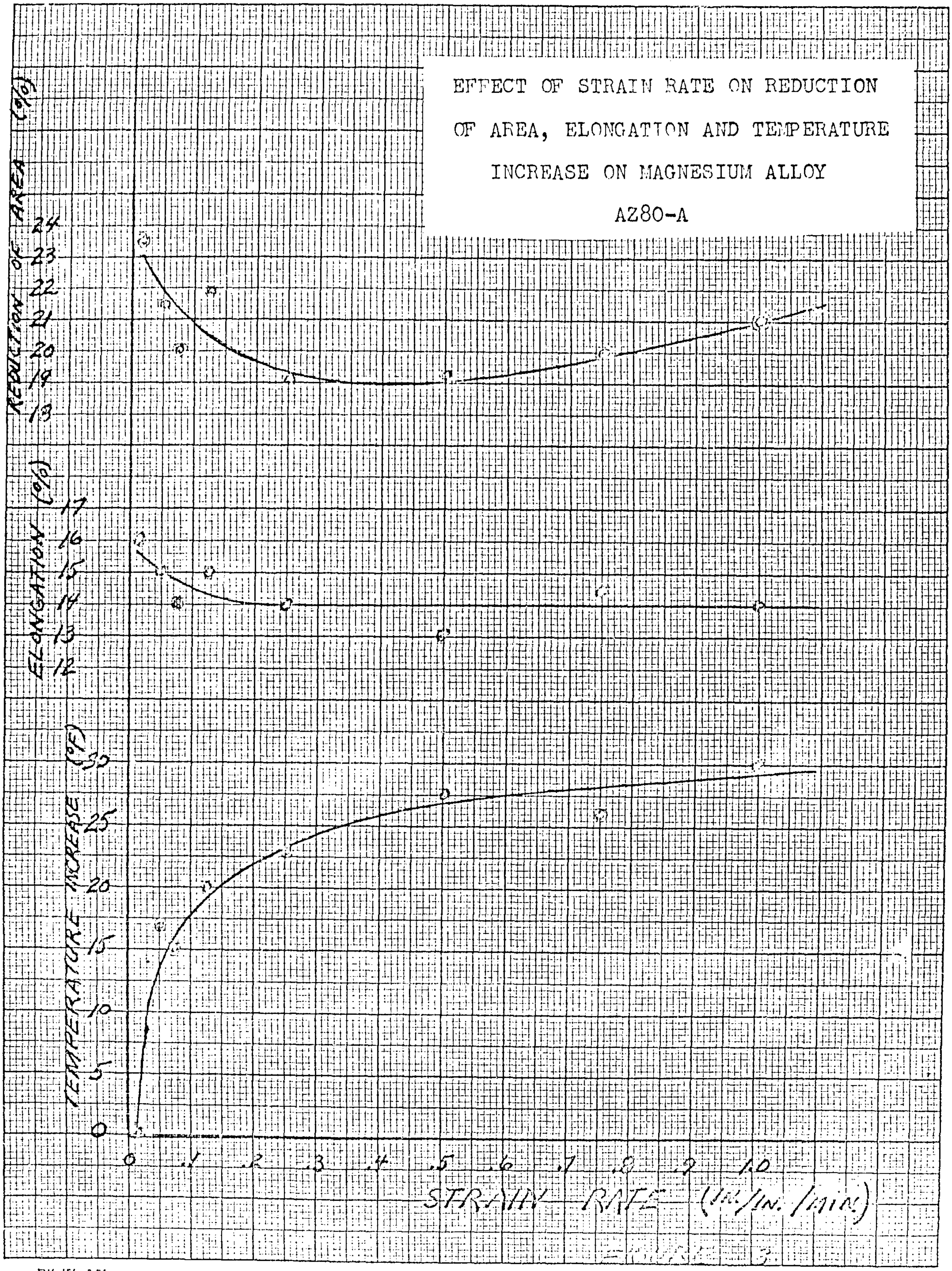

EFFECT OF STRAIN RATE ON REDUCTION
OF AREA, ELONGATION AND TEMPERATURE
INCREASE ON 4130 STEEL
REDUCTION OF AREA (%)
57
56
55
54
53
ELONGATION (%)
33
31
29
27
25
23
TEMPERATURE INCREASE (°F)
160
140
120
100
80
60
40
20
0
0
.2
.4
.6
.8
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
STRAIN RATE (in/in/min)
ANNEALED
HEAT TREATED TO 200 KSI

FIGURE 2

EFFECT OF STRAIN RATE ON REDUCTION OF AREA, ELONGATION AND TEMPERATURE INCREASE ON MAGNESIUM ALLOY AZ80-A



EFFECT OF STRAIN RATE ON REDUCTION OF AREA, ELONGATION AND TEMPERATURE REDUCTION OF 4130 STEEL

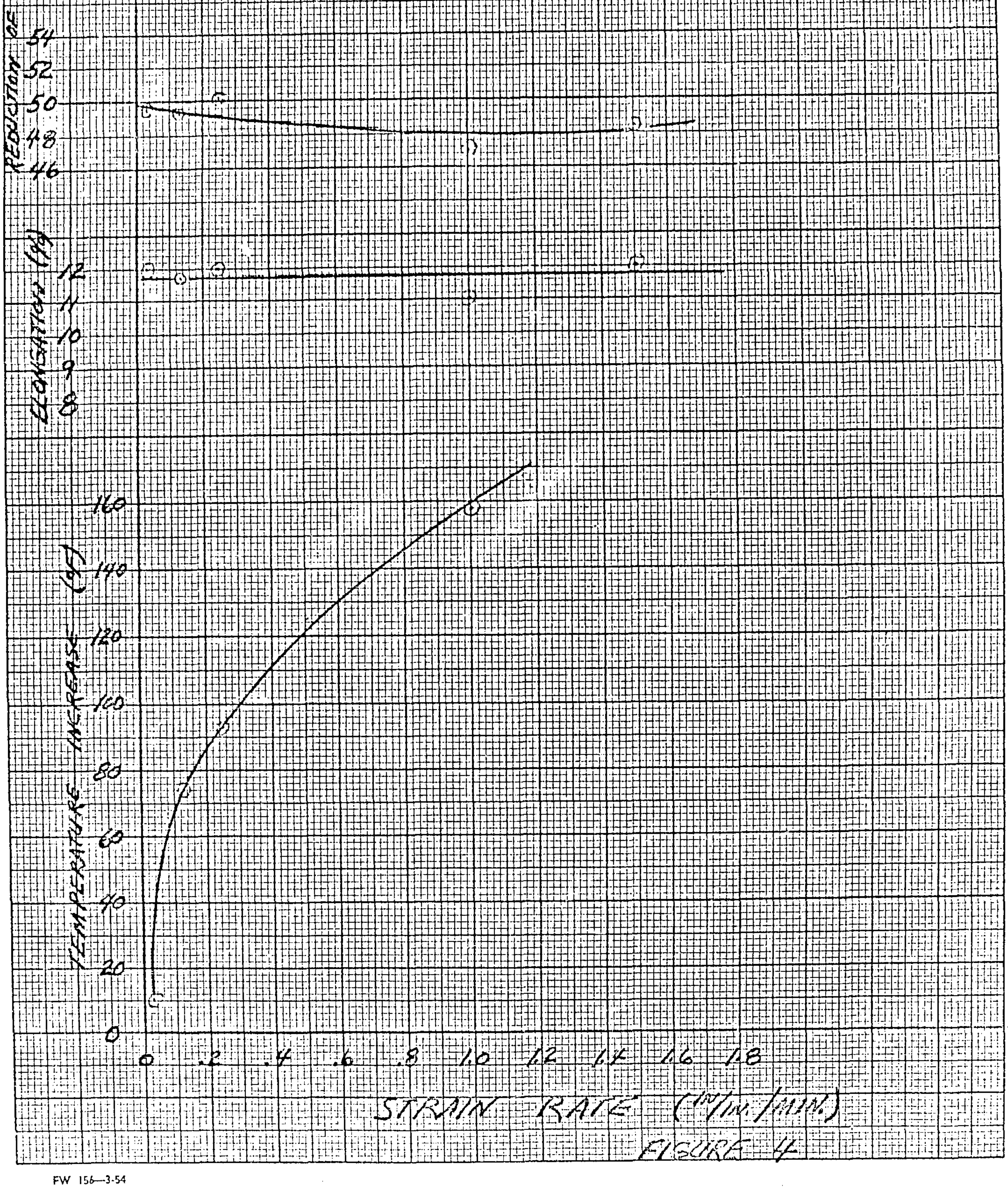


FIGURE 4

[illegible]